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CONCEPTUAL MODEL OF THE FUNCTIONAL STRUCTURE OF AUTOCHTHONOUS COMPONENT IN SOIL MICROBIAL ORGANISMS COMMUNITIES

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Abstract

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Considering the actual state of knowledge in the sphere of the soil microorganisms ecology and the humus dynamic process in soil one may suppose that the following functional groups of microorganisms take part in humus transformation (decomposition):

— hydrolytic microorganisms producing extracellular hydrolases, as r-strategies. Soil micromycetes, non sporulating bacteria and streptomycetes are typical hydrolytics,

— patienotrophes producing oxidases of aromatic compounds, as L—strategies. It denotes *Nocardia, Microbacteria, Rodococks* and all other microorganisms stubbornly, "patiently" decomposing aromatic substrates do not produce hydrolytic enzymes which has the consequence that they practically do not take part in assimilation of fresh organic residues penetrating into the soil,

— oligotrophes characterized by active cellular transport of monomere compounds from low concentrations of the surroundings, as K-strategies, they have an important role in completing the decomposition of humus matter in soil. This supposed functional structure of autochthone part of soil microorganisms cenoses is not at variance with ecological paradygm and explains a number of questions connected with the decomposition of humus in soil, its stability and dynamics.

The functional trend in the soil microorganisms ecology was formed already in the time, when the soil microbiology came into existence especially in the classical works by Winogradsky (1938, 1952). Coming out of the fact that two contradicting processes are going on in the soil, the decomposition of organic residues (plants, animals) leading to the creation of new humus substances on the one hand and the decomposition of humus components on the other, he expressed the hypothesis, according to which there exist two in quality different groups of microorganisms, each of them being responsible for one of those processes. The microorganisms decomposing organic matter and forming humus were defined as zymogenic microflora and those, responsible for decomposition of humus as autochthonous microflora (compare with autochthonous as native microflora as distinct from allochthonous microflora). But of course Winogradsky did not succeed in identifying the representatives of the second named native group and consequently, up to these days, this part of Winogradsky's hypothesis has been still an open question.

The science on the microbial soil system was further developed especially in the works of Zavarzin (1976). Zavarzin proposed "The ability of microorganisms to produce extracellular hydrolytic enzymes" to be taken as a criterion of differentation of functional groups, because their concentration in the environment determined the rate of matter tranformation in the whole system. In this process a part of created monomers does not penetrate into the hydrolase produces but is dispersed in the surroundings. The microorganism group, although not producing extracellular hydrolases but able to take the products of hydrolysis in the dispersed state, is defined by Zavarzin (1970) as dispersion microflora. In his presented scheme of soil microorganisms communities the group of humus decomposing microorganisms is strictly defined (the autochthonous group).

That scheme was later simplified by Mishustin (1975), but the soil decomposing group remained. In relation with Winogradsky's works Guzev, Ivanov (1986) proposed a functional structure model of zymogenic microflora.

In today's microbiological literature the term "oligotrophic" instead of "autochthonous" and "copiotrophic" instead of "zymogenic" are often used (Kaczmarek, W., 1985; Kaszubiak, H., Muszyńska, M., 1987; Lynch, 1989).

This fact complicates the further evolution of soil microorganisms ecology, because the couples of terms cannot be considered as synonyma.

Humus matter as a microbial substrate

The phenomenon of the world wide decrease of soil humus evoked an extraordinary interest in autochthonous microflora in the course of the latest years. Methodological problems in the research of that microorganisms group are connected with the difficulties joint to the research of humus matter as a microorganism substrate: their structure (Murzakov, 1972, 1988), mechanisms of bioconversion and so on. Especially those difficulties led to the false conclusion that "the matter of humus is very inert" (e. g. Nikitin, Nikitina, 1978, p. 19). The same way the understanding of humus matter as a natural-products-group, consisting of high-molecular compounds of a specific character, demonstrating a stability towards biological and chemical influences (Tyurin, 1937; Dragunov, 1950; Alexandrova, 1980; Kononova, 1963).

In the same time it is admitted, that humus is always accompanied in soil by a great quantity of microorganisms, that they are even "cemented" to the humus. It can have no other significance than that an interaction between microorganisms and humus components is going on although in a slow way.

A number of hypotheses — conceptions was declared to make clear the high stability of humus towards microorganisms (Alexandrova, 1962; Orlov, Denisova, 1962; Kleinhempel, 1978). In consideration of this problem it is necessary to take into account, that most probably humus consists of much and little stable fractions that came into existence thousands of years ago (Gerasimov, 1968). So for example Sauerbeck (1968) asserts that there are two pooles of organic matter: labile and stable or native forms which are immediately connected with soil-forming processes.

On the basis of the data obtained from the characteristics of humic acids it is possible to construct a partly scheme of their basic components (see Table 1).

The relative representation of each group may be different, especially when we count on a high heterogeneity of humic acids, but in principle it gives a basic idea about their structure.

The basic forms of nitrogen in humic acids have the representation as follows: N-aminoacids 18 %, N-amines 9 %, N-heterocyclic compounds 49 %, N-dissoluble compounds 22 %; in fulvicacids: N-aminoacids 45 %, N-heterocyclic compounds 22 %, N-amines 16 %, N-dissoluble compounds 15 %.

The nitrogen of fulvic acids is hydrolyzed to 70 %, the nitrogen of humic acids to 40—60 % (in dependence on the soil type).

In hydrolyzates of humic acids there are hexoses, pentoses, saccharose, cellobiose, cellotrioses, mannite, inosite, methylsaccharides and amino-saccharides.

Ecological humus transformation group of microorganisms

Considering the actual state of knowledge in this sphere it may be supposed that the following functional groups of microorganisms take part in humus formation:

- hydrolytic microorganisms producing extracellular hydrolases,
- patienotrophes producing oxidases of aromatic compounds,
- oligotrophs characterized by active cellular transport of monomer compounds from low concentrations of the surroundings.

Among those groups of microorganisms and the respective humus- components exist very complicated chemical, biological and ecological relations variable in time and place.

Table 1. Basic humus compounds structure (Alexandrova, 1980)

Component	[%]
Aromatic and heterocyclic part: purine and pyrimidine bases aromatic aminoacids and fenotazones one- and many members aromatic cores substitution by fenoles and chinones on different degrees	30—35
Alifatic and acyclic parts: amino-acid groups carbohydrates	25—40
Functional groups: —COOH (—OH), —OH, =CO, COH	35—10

Hydrolytic microorganisms

The group of hydrolytic microorganisms is characterized by the production of extracellular hydrolases. On the base of the fact, that they secret hydrolytic enzymes, these organisms increase the monomere concentration in their surroundings and in this way they ensure their priority — development. Soil micromycetes (Mirchink, 1984) non sporulating bacteria and streptomycetes (Mishustin, 1984) are typical hydrolytic organisms.

For hydrolytic microorganisms it is possible to use peripheral parts of humus acids which as substrate contain peptides and polysaccharides. That is why we (Andreyuk, Gordienko, Gavrish, 1975, 1978; Gordienko, Kunc, 1982, 1984; Gordienko, 1986) find substantially less aminoacids in hydrolyzates of humic acids from intensively cultivated chernozem than in native soil.

Experiments done with special preparates of humic acids, labelled by isotope ^{15}N, show, that ^{15}N is being incorporated the cell microorganisms with hydrolytic activity: streptomycetes, micromycetes, bacteria. In this process changes in molecular mass structures were observed: a higher representation of high-molecular fractions and the reduction of the low-molecular ones.

Under the microorganisms influence the total contents of nitrogen and isotope ^{15}N in fractions with high and medium molecular mass are reduced and on the contrary this nitrogen appears in fraction with lower molecular mass. It means that nitrogen from high-molecular fractions is accessible for microorganisms.

The phenomenon diauxy can be observed in humic acids destruction. Glucose causes the increase of biomass of organisms, growing on humate media (Gordienko, Kunc, 1982, 1984). The ability to use nitrogen from humic acids could be found in a number of microorganisms' species. The intensity of nitrogen accumulation from humus in biomass is higher in associations of microorganisms as a consequence of synergic influence on humic acids in those species associations of microorganisms.

Patienotrophs

(The name "patienotrophs" is used for the first time here. It denotes *Nocardia, Micobacteria, Rhodococcus* and all other microorganisms "tolerantly", "patiently" (lat. patiens) decomposing aromatic substrates.) Patienotrophs do not produce hydrolytic enzymes which has the consequence that they practically do not take part in assimilation of fresh organic residues penetrating into the soil. The utilization of the products of protein-contain hydrolysis, polysaccharides and partly disaccharides, too, on which they well develope in pure cultures, is slowed down by antagonic activities of singular hydrolytic representatives. These microorganisms play the basic role in the decomposition of hardly accessible components: humus matter, carbohydrates, lignine etc.

Among them nocardia and coryneform bacteria, capable to effect the bioconversion of aromatic compounds, have a special importance (Orchad, 1981; Nesterenko et al., 1985). The vitality of nocardia and mycobacteria in unfavourable conditions, arising e. g. in lack of water and nutrients in soil, is given by hydrophility of their cellular walls, the presence of wax, glycerids, poly-ß-oxybutyrates, glykogen and other energetical substrates. These microorganisms are noted by their ability of growth in a relatively broad diapazone concentration of organic matter. They are able to grow even at low temperatures which can be explained by a high elasticity of their cells. In dry state they are able to live for 2-3 years (Cross, Rowbotham et al., 1976; Linder, 1973; Schaal, Pulverer, 1981).

Nocardia and other representatives of this group of microorganisms are not sensitive to nitrite most of them using it as a source of nitrogen. Nitrite has not only physiological but also ecological significance for them. Nocardia contains nitrate-reductase transforming nitrates to nitrites inhibiting hydrolytic microorganisms (Nesterenko et al., 1985).

As to the role of phenoloxydase in humic substance degradation there is an opinion at the present time that a phenolase activity does not always cause the destruction of humic acids. After the discovery of cellobiosochinonoxidase (Westermark, Eriksson, 1974) the connection between the catabolism of lignine and cellulose was stated. This enzyme oxidises cellobiose into cellobiolacton and paralelly catalyzes the reverse-reaction of phenol into chinon. The presence of chinon slows down the decomposition of the aromatic core and this way also the degradation of lignin, the presence of cellulose supports the reduction of chinone to phenol and the decomposition of lignine and the presence of laccase aids the formation of chinon or phenol radicals, provoking spontaneous polymerization — reactions in which high-molecular compounds come into existence.

Oligotrophic microorganisms

Under the name of oligotrophic microorganisms we understand in accordance with Mishustin (1975, 1982, 1984) a functional group of microorganisms having a system of active transport of low polymere concentrations from the environment to the cell. Therefore the decrease of monomer concentration in soil favours the oligotrophs complete to other microorganisms. This way the oligotrophs complete in soil the decomposition of organic matter, which is represented by organic monomers (Nikitin et al., 1966; Vasilyeva, 1980; Vasilyeva, 1984).

We divide the oligotrophic microorganisms in obligatory (Prostecobacteriaceae) and facultative (*Pseudomonas*). A number of microorganisms of the group of facultative oligotrophs assist to the final phases of aromatic monomer decomposition (Malceva, Gordienko, Izžeurova, 1974). From these functional groups of microorganisms have different ecological groups of plants (Ramensky, 1938) and animals groups (Whittaker, 1975) (see tab. 2).

Table 2

Distinguishing groups (communities)	General properties
Hydrolytics	High degree of capacity to produce extra-cellular hydrolases.
Explerents (Ramensky, 1938)	Capacity of rapid taking advantage area and (or) period of week competition.
r — strategy (Whittaker, 1975)	Population number fluctuates from the highest to the lowest point.
Patienotrophs	Higher capacity to oxidize the aromatic substances.
Patiensts (Ramensky, 1938)	Capacity of development in environment negative for another organisms
L — strategy (Whittaker, 1975)	Population number retains on the lowest point
Oligotrophs	Higher capacity of active transport of monomers in a low-concentration.
Violents (Ramensky, 1938)	Capacity of maximum utilization of environment resource.
K — strategy (Whittaker, 1975)	Its maximum number is the carrying capacity of the environment.

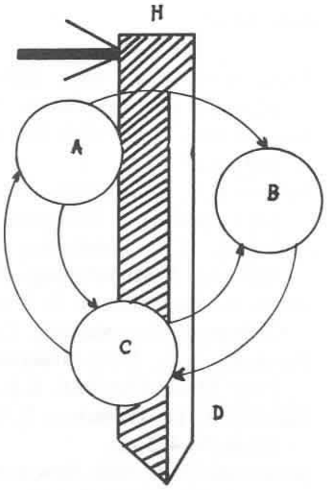

Fig. 1. The scheme of soil autochthonous microflora functional structure.
A — Hydrolytics, B — Patienotrophs, C — Oligotrophs, D — H_2O, CO_2, H — Humic substances.

But the "polyfunctionality" of microorganisms does not allow to fix exact analogies between systematic pertenance and functional groups of microorganisms.

It is possible to imagine the microbial system in soil, ensuring aerobic heterotrophic mineralization of humus in soil, as a triad, consisting of hydrolytic microorganisms, patienotrophs, and oligotrophs (Fig. 1). The homeostatical mechanism of such a system is ensured by subsequent activities of these three functional microorganisms groups. Signal metabolites of the system are monomer compounds formed in fermentation processes proceeding in soil.

The activity regulation of individual functional microorganisms groups occurs on the principle of catabolic repression, inhibition by substrate and is secured on the principle of the negative feedback.

The synthesis of extracellular hydrolases, which secure the exploitation of peripheral parts of humic acids, is function of hydrolytic microorganisms.

The function of patienotrophs is the ability to produce oxydases of aromatic compounds and the exploitation of aromatic structures in humus compounds.

The function of oligotrophs is the exploitation of monomer compounds. In the low concentrations they have an important role in completing the decomposition of humus matter in soil.

This supposed functional structure of autochthonous part of soil microbial cenoses is not at variance with ecological paradigm and explains a number of questions connected with the decomposition of humus in soil, its stability and dynamics.

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Gordienko, S.: **Konceptuální model funkcionální struktury autochtonní složky společenstva půdních mikroorganismů.**

Na základě současného stavu poznání v oblasti funkcionální struktury autochtonní složky mikrobních společenstev půdy lze tvrdit, že na transformacích humusu se podílejí následující funkcionální skupiny mikroorganismů: hydrolytické mikroorganismy, produkující extracelulární hydrolázy, patienotrofy, produkující oxidázy aromatických sloučenin, a oligotrofy, vyznačující se aktivním buněčným transportem monomerních sloučenin z nízkých koncentrací okolního prostředí. Mezi těmito skupinami mikroorganismů s příslušnými komponenty humusu existují velmi složité, obecně, časově a prostorově proměnné chemické, biologické a ekologické vztahy.

Skupinu hydrolytických organismů vyznačuje produkce extracelulárních hydroláz. Na základě toho, že v blízkosti svých buněk vylučují hydrolitické enzymy, tyto organismy zvyšují ve svém okolí koncentraci monomerů, čímž zabezpečují svůj přednostní vývoj.

Patienotrofy jsou charakteristické tím, že neprodukují hydrolytické enzymy. To má za následek, že se prakticky nezúčastňují asimilace čerstvých organických zbytků, které pronikají do půdy. Využívání produktů hydrolýzy bílkovinných sloučenin, polysacharidů a částečně i disacharidů, na nichž se v čistých kulturách dobře rozvíjejí, je v půdě brzděno protichůdným působením jednotlivých reprezentantů hydrolytiků. Tyto mikroorganismy hrají základní úlohu při rozkladu těžce přístupných komponentů: humusové látky, uhlovodíky, lignin apod. Mezi nimi mají zvláštní význam nokardiepodobné a koriněpodobné bakterie, schopné uskutečnit biokonverzi aromatických sloučenin.

Nokardie a ostatní představitelé této skupiny mikroorganismů nejsou citlivé vůči nitritům; většina je využívá jako zdroje dusíku. Nitrit pro ně má význam nejen fyziologický, ale i ekologický. Obsahuje nitrátreduktázu, která transformuje nitrát na nitrit, inhibující hydrolytické mikroorganismy.

V konečných fázích rozkladu aromatických monomerů působí řada mikroorganismů ze skupiny fakultativních oligotrofů.

Гордиенко С.: **Концептуальная модель функциональной структуры автохтонной части сообщества почвенных микроорганизмов.**

Предлагается концептуальная модель автохтонной части, в смысле Виноградского, сообщества почвенных микроорганизмов, которая предполагает участие следующих групп микроорганизмов, принимающих участие в разложении гумусовых веществ: микроорганизмы — гидролитики, продуцирующие экзогидролазы, патиенотрофы, продуцирующие оксидазы ароматических соединений и олиготрофы, характеризующиеся активным клеточным транспортом мономеров из низких концентраций окружающей среды. Между этими группами микроорганизмов существуют сложные временные и пространственные взаимоотношения. Группа гидролитических микроорганизмов выделает в окружающую среду повышенные концентрации мономеров, чем обеспечивает свое преимущественное развитие. Патиенотрофы не выделяют гидролитические ферменты и практически не принимают участие в разложении свежих растительных остатков растительного и животного происхождения, которые попадают в почву. Использование продуктов гидролиза белков, полисахаридов и дисахаридов, на которых в чистых культурах хорошо развиваются, в почве тормозится противоположно направленной деятельностью отдельных представителей микроорганизмов — гидролитиков. Патиенотрофы играют основную роль в разложении труднодоступных компонентов: гумуса, углеводородов, лигнина и т. п. Между этими микроорганизмами особое значение имеют нокардие- и коринеподобные бактерии, способные

осуществлять биоконверсию ароматических соединений. Нокардии и другие представители этой группы микроорганизмов не чувствительны к нитритам, так как содержат нитратредуктазу и используют нитриты в качестве источника азота. В свою очередь нитриты ингибируют гидролитические микроорганизмы. На заключительной стадии разложения гумусовых веществ принимают участие микроорганизмы — олиготрофы.